Detailed numerical simulations of laser cooling processes

Jaime Ramirez-Serrano, James Kohel, Robert Thompson and Nan Yu
Jet Propulsion Laboratory, Quantum Sciences and Technology Group,
California Institute of Technology, Pasadena, CA 91109

ABSTRACT

We have developed a detailed semiclassical numerical code of the forces applied on atoms in optical and magnetic fields to increase the understanding of the different roles that light, atomic collisions, background pressure and number of particles play in experiments with laser cooled and trapped atoms. We also discuss the use of the model in the design of cold beam sources for future studies.

SUMMARY

Since the development of laser cooling and trapping techniques many authors have worked on the experimental and theoretical [1] understanding of the role played by the different laser-atom and atom-atom interactions involved in the process. Much of the understanding has been accomplished by performing simulations that show similar characteristics as the ones observed during the experiments [1,2]. However, due to the complexity of the processes involved, the energy multilevel characteristics of the atoms, and the great number of particles involved, most simulations incorporate only a limited number of these interactions to compute the gross features of a particular experiment. In the development of robust instruments that use cold atoms many more interactions need to be considered to design a functional and robust prototype.

Some of the aspects that we also consider in our model, besides the normal scattering forces involved during laser cooling experiments, are the influence of background pressure, total number of particles, laser attenuation by near-resonant atoms, and atomic collisions with cold and background atoms. All these different processes that are involved during normal experiments are taken into account simultaneously during the simulations and give us the ability to turn them on and off to observe their role. Dipole, gravitational and other field forces are considered as well.

We have used the code to fully understand the role that different interactions have in the features seen in a cold atomic beam source [3]. To fully consider the role of atomic collisions up to 500,000 atoms, limited only by computational time, are used in the simulations. Atomic collisions with background atoms, and transverse heating, in a cold atomic beam resulting from a pyramidal magneto-optical trap currently in our lab have shown to be important aspects to consider for a better match between experimental and theoretical values in the divergence of the atomic beam. See Fig. 1. The calculated longitudinal velocity distribution of atoms in the atomic beam dramatically approaches the experimental values at small detunings from resonance when laser attenuation produced by near-resonant atoms is taken into account. See Fig. 2.

A dual-species cold atomic beam source currently working in our laboratory is being simulated and we will present the results of this work. The code is also being used to design a compact beam source of cold atoms to employ in future ground and flight experiments for the International Space Station. Plans are also underway to understand the effects of the various interactions in the achievement of an all-optical Bose-Einstein condensate [4].

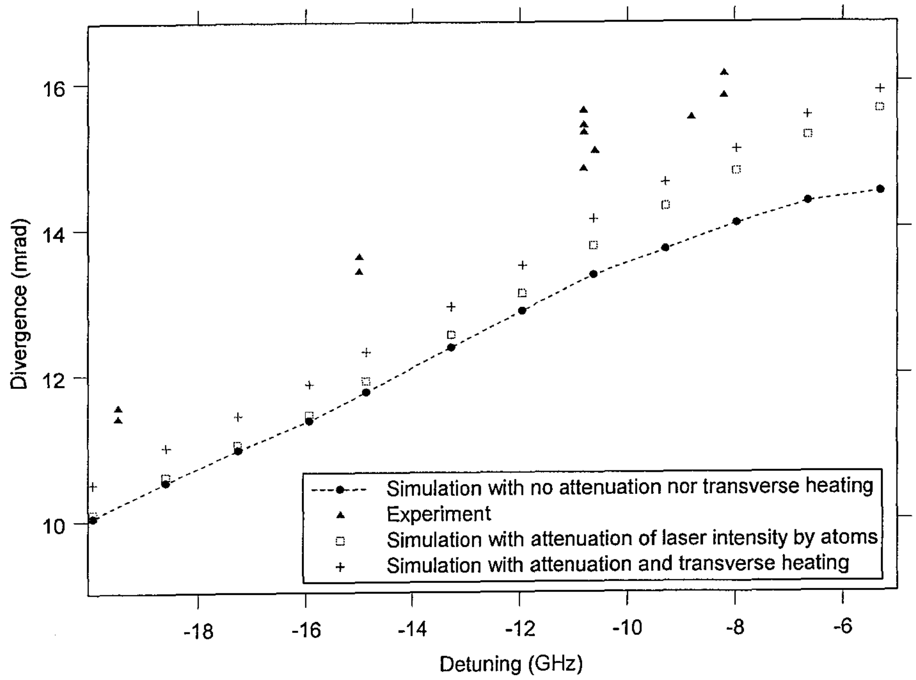

Figure 1.- Atomic beam divergence of cold Cs atoms emerging from a PLVIS cold beam source as a function of laser detuning from atomic resonance.

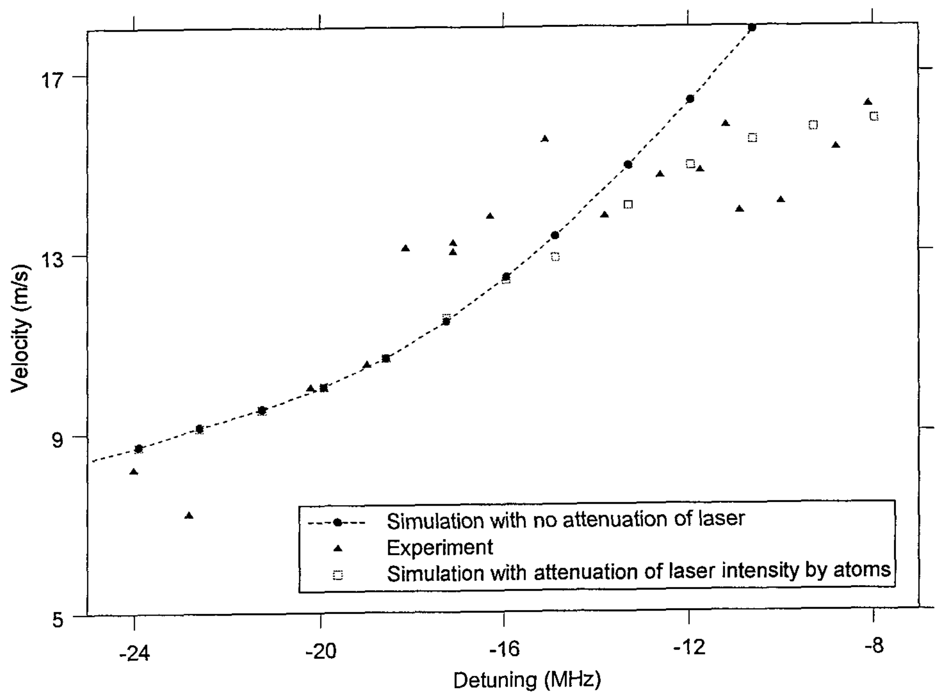

Figure 2.- Atomic beam longitudinal velocity of cold Cs atoms emerging from the same PLVIS system as in Fig. 1. Laser attenuation plays an important role to match theoretical values at small detunings with experimental measurements.

REFERENCES

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